THE BIGHORN SHEEP OF THE SHEEP RIVER VALLEY

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THE BIGHORN SHEEP OF THE SHEEP RIVER VALLEY

A DISSERTATION

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

FACULTY OF ARTS AND SCIENCE

DEPARTMENT OF ZOOLOGY

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EDMONTON, ALBERTA

April, 1958.

ABSTRACT

The type specimens of Rocky Mountain bighorn sheep Ovis canadensis canadensis Shaw, were collected near Exshaw, Alberta in 1804. Since that time there has been a general decline in their numbers as a result of encroaching civilization. In 1954 a study was begun near the headwaters of the Sheep River in southwestern Alberta to determine the present status of the bighorn sheep. The herd under observation averaged 62 individuals over a period of four years. Ewes and yearlings appeared on the winter range in relatively constant numbers each year. On the other hand, ram numbers fluctuated each year due to changing hunting regulations and breeding behaviour. In spite of irregular ram - ewe ratios there was no apparent effect on lamb production. The productivity was found to be low; the ewes did not breed until two and a half years of age, rarely had twins, and lived for only seven to ten years. Accidents, predators, parasites and disease are believed to be taking a steady toll. Competition for food with other animals is not believed to have reached serious proportions so far. Varied amounts of available forage on the winter range appeared to have no influence on the numbers of sheep that returned each year. It was concluded that the numbers of sheep on the study area were regulated by intraspecific tolerances

and by the amount of open range found near escape terrain. It is believed that excess sheep on marginal areas of open timber or high wind-swept slopes are subject to a high mortality due to predation and severe snow conditions.

Management problems are discussed and it is thought that rams with slightly less than an actual 3/4 curl should be taken in order to harvest the heads with horns that are broomed or have wide spreads. Winter range improvements are considered and it is recommended that cattle, elk and dense poplar stands be removed from the sheep winter range. An experimental transplant of bighorns to the Provincial Park at Steveville is suggested.

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INTRODUCTION

The Rocky Mountain bighorn is presently listed as Ovis canadensis canadensis Shaw (Miller and Kellogg, 1955). Ovis canadensis was first described in 1804 by Dr. George Shaw of the Royal Society of London. The specimens that Shaw received were collected by Duncan McGillivray along the Bow River near Exshaw, Alberta (Seton, 1929). According to Cowan (1940) four subspecies (canadensis, californiana, nelsoni and mexicana) occupy the bulk of the species' range. Ovis canadensis canadensis is presently confined to the Rocky Mountains north to the 54th parallel and south into Colorado.

Smith (1954) noted that there is much evidence in American historical records that bighorn sheep once roamed river valleys far from their present rugged habitat. When Mr. H. U. Green, Warden at Banff National Park, first came to Alberta in 1922 he found remains of bighorn sheep near Brooks and in the Sweet Grass Hills (pers. comm.). Even within recent years bighorns have been reported along the Red Deer and Sheep Rivers as far as 30 miles east of their present range.

Bighorns that inhabited river valleys and foothills were subjected to steady hunting pressure by meat and trophy hunters, devastating epizootics and steady encroachment of range by livestock. As a result there was a marked decrease in their numbers during the late nineteenth and early twentieth

Fig. 1. Part of the Luxton collection of bighorn sheep skulls.

centuries (Honess and Frost, 1942).

In 1859 the Earl of Southesk described hunting bighorns in the Embarrass River country of Alberta (Couey, 1950). According to Millar (1916) Stony Indians took a large toll of bighorn sheep in the early 1900's. During the hunting season of 1913 Millar and a forest officer visited 14 Stony hunting camps and found close to 200 sheep kills. Millar estimated that the Indians had killed 600 sheep in that year alone. About the same time Mr. N. K. Luxton, former museum curator at Banff, "secured several hundred sheep skulls" at Morley from two traders; David McDougal and Leason and Scotts posts (pers. comm.). One trading post had stored over 700 sheep skulls. Over eighty of the skulls are now stored in the basement of Mr. Luxton's store in Banff (Fig. 1). According to Luxton, mounted game heads were popular in the early days and the Indians were able to use sheep skulls as trading material for flour, tea and salt. The white man in turn bargained with the traders for the skulls. Some of the skulls went to museums, others went as mounted heads as far away as Europe and the British Isles. Following Millar's report to Ottawa the annual slaughter of bighorns was apparently stopped.

By the 1880's scabies had greatly reduced the sheep numbers to the south in Montana and Wyoming (Couey, 1950) and doubtless the epidemic spread into Alberta. Trappers and ranchers reported that pneumonia caused heavy sheep losses in the Highwood and Sheep River drainages in the early forties. The sheep of other ranges may have been infected as well. Since that time sheep numbers have risen slowly and remained relatively constant for the last ten years. In 1916 Millar estimated the numbers of bighorn outside of Rocky Mountains Park (Banff Park) to be not less than 1,275 head and not more than 2,700 head. Provincial game biologists estimate the present numbers of bighorn outside of the National Parks to be not less than 2,600 and not more than 3,300 head.

Until recently the bighorn has been little studied outside of the National Parks. On May 4, 1955, a detailed study of a hunted sheep herd in the Sheep River drainage system was begun. The purpose of the study was to collect as much information about this comparatively rare big game mammal as possible in order to aid in its management. The study period was limited to the period from May to September each year until 1957 and as a result many of the winter influences on the life history of the bighorn are not known from direct observations. The main objectives of the study were to find:

(1) Age and sex composition of the herd.

(2) Ratio of dry to pregnant ewes.

(3) Lambing success and dates of lambing.

(4) Seasonal movements.

(5) Grazing requirements.

(6) Mineral requirements.

(7) Mortality rates.

Other objectives partly related to practical management were investigated as well. These included the above historical review and a study of horn growth.

Headquarters for the study were at the Alberta Biological Station located at the confluence of Gorge Creek and the Sheep River. Funds for the study were made available by the University of Alberta, the Provincial Fish and Game Branch and two wildlife fellowships from Canadian Industries Limited. The study was under the supervision of Dr. R. B. Miller, Professor of Zoology, at the University of Alberta.

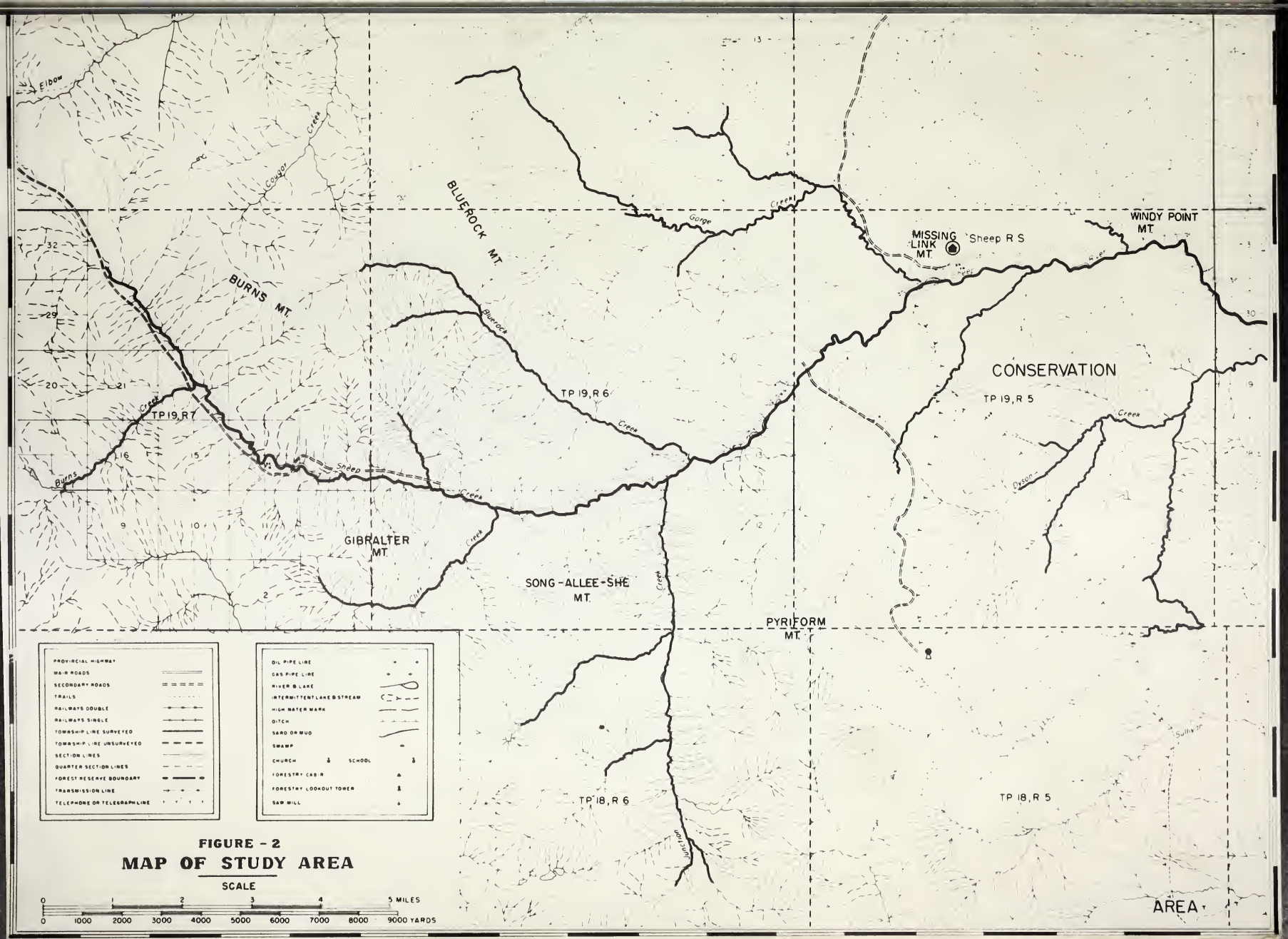


FIGURE - 2

MAP OF STUDY AREA

DESCRIPTION OF STUDY AREA

The study area was confined to the upper portion of the Sheep River drainage system, an area of approximately four and one-half townships (Fig. 2). The headwaters of Burns Creek marked the western and Windy Point Mountain the eastern limit. The headwaters of Gorge Creek marked the northern and the headwaters of Junction Creek the southern limit. From east to west the altitude rises from 4,000 feet to 10,000 feet above sea level.

The Sheep River forms a deep gorge in the softer shales of the lower regions after it leaves the hard rock formations of the higher altitudes (Fig. 3). This provides a natural route for the summer and winter movements of the bighorn. The rugged escarpments of Pyriform, Bluerock, Song-allee-she, Gibraltar and Burns Mountains provide lambing and bedding grounds as well as essential escape terrain for the sheep during the summer months (Fig. 4). The considerably smaller escarpments of Missing Link and Windy Point Mountains and the walls of the Sheep River canyon provide bedding and escape terrain during the spring and winter months (Figs. 5 and 6). The walls of the Sheep River canyon are also utilized as licks for their natural mineral deposits by ewes and immature animals during the summer.

Fig. 3. Sheep River canyon, migration route of bighorn.

Fig. 4. Gibraltar Mountain, lambing grounds and summer escape terrain of bighorn.

Fig. 5. Escape terrain of Missing Link Mountain.

Fig. 6. Five yearling rams utilizing escape terrain of the Sheep River canyon.

The winter range of the bighorn is typical parkland, i.e., a mosaic of prairie patches and aspen groves, with prairie occupying the south slopes and aspen (Populus tremuloides Michx.) occupying the ravines and flat areas. According to long-time residents of the district a considerable amount of former open range has been invaded by poplar growth in the last twenty years. The higher summer range may be considered as unlimited. The Boreal-Cordilleran and Subalpine forests (Moss, 1955) occupy the zone between the winter and summer ranges. The Boreal-Cordilleran forest is largely white spruce (Picea glauca (Moench) Voss) up to the 5,700 foot level; higher, there is a mergence with the Picea engelmanni Parry, Abies lasiocarpa (Hook.) Nutt. association of the Subalpine forest. The stunted subalpine species or "krummholz" begins at 7,000 feet and extends onto the meadows of the alpine region. The feeding areas of the bighorn are confined to the Festuca scabrella Torr. association of the winter range and the alpine meadows of the summer range.

The frequency or availability of the different plants on the feeding areas was determined during the summer of 1956 by a line transect method described by Smith (1954). Fifteen line transects 100 feet long were permanently located on winter and summer feeding areas and the plants that were intercepted at foot intervals were recorded. The plant frequencies in the different transects were combined for a given area and appear as percentages in Tables I and II.

Table I. Percentage of plants and exposed areas intercepted by eight 100 foot line transects on bighorn sheep winter range. (Plants after Budd, 1952).

Grasses and sedges	Percentage
Agropyron spp.	8.0
Bromus spp.	1.4
Carex spp.	6.7
Danthonia spp.	0.5
Elymus innovatus	0.1
Festuca scabrella	2.8
Koeleria cristata	11.6
Muhlenbergia sp.	0.4
Phleum pratense	1.0
Poa sp.	0.1
Stipa columbiana	0.1
Total	32.7
Shrubs	**Percentage**
Amelanchier alnifolia	0.8
Eleagnus commutata	0.1
Juniperus horizontalis	0.2
Potentilla fruticosa	1.2
Ribes setosum	0.1
Rosa acicularis	2.1
Salix spp.	0.1
Symphoricarpos occidentalis	2.0
Total	6.6
Forbs	**Percentage**
Agoseris sp.	0.6
Antennaria anaphaloides	0.1
Artemesia frigida	5.4
Artemesia dracunculoides	0.1
Aster sp.	0.4
Astragalus spp.	1.5
Campanula rotundifolia	0.5
Galium boreale	1.1
Lupinus leucopsis	0.1
Oxytropis spp.	2.2
Phlox hoodi	0.3
Potentilla sp.	0.3
Solidago spp.	0.6
Taraxacum officinale	0.1
?	0.4
Total	13.7
Exposed Areas	**Percentage**
Bare rock	10.5
Dead mat	9.1
Bare ground	27.4
Total	47.0

Table II. Percentage of plants and exposed areas intercepted by seven 100 foot transects of bighorn sheep summer range.

Grasses and Sedges	Percentage
Agropyron spp.	3.5
Bromus spp.	1.9
Carex spp.	9.6
Elymus innovatus	3.0
Festuca scabrella	3.0
Koeleria cristata	7.6
*Muhlenbergia sp.	0.4
Poa spp.	1.0
*Stipa columbiana	2.0
Total	32.0

Shrubs	Percentage
Juniperus horizontalis	6.6
Populus balsamifera	0.7
Potentilla fruticosa	2.6
Ribes setosum	0.2
Rosa acicularis	0.3
Salix sp.	0.2
Total	10.6

Exposed Areas	Percentage
Bare rock	12.6
Dead mat	10.0
Bare ground	5.7
Total	28.3

Forbs	Percentage
Achillea lanulosa	1.1
Agoseris sp.	2.0
Androsace septentrionalis	0.2
Antennaria sp.	0.3
Arctostaphylos uva-ursi	3.6
Aster sp.	0.4
Astragalus spp.	0.6
Cerastium sp.	1.1
Cirsium spp.	0.3
*Cruciferae	0.2
Epilobium angustifolium	0.2
Fragaria glauca	1.4
Galium boreale	1.1
Hedysarum spp.	1.7
Lathyrus sp.	0.2
Moss	1.9
Oxytropis spp.	3.7
Potentilla spp.	3.7
Primula sp.	1.0
Pulsatilla ludoviciana	0.4
*Saxifraga rhomboidea	0.2
*Sisyrinchium angustifolium	1.6
Smilacina sp.	0.2
*Taraxacum officinale	0.6
?	1.4
Total	29.1

*Plants that did not appear in transects of alpine meadows.

DESCRIPTION OF BIGHORN SHEEP

The bighorn is a large sheep, squarely built with slender legs, short tail and somewhat tapered muzzle. The front hoofs are much larger than the hind ones which probably is an adaptation for climbing and checking downhill dashes with the forelegs and feet. The pelage varies in color from chocolate-brown to grey-brown in the summer and fall with lighter colored undersides, muzzle and rump patch. Coloration is extremely variable even in the same band; however, during the winter all the various coat colorations of the ewes and juveniles become light and drab and by spring-time all individuals are similar. Generally speaking, rams that are three or more years old retain a dark coat.

The coat consists of two dissimilar fibers forming a dense outer layer of coarse hair and a loose inner layer of fine fibers. Honess and Frost (1942), describe the fibers of the inner coat as consisting of two types, true wool fibers and hair fibers, or medullated wool fibers. The hairs of the outer coat have dark tips, hence the dark appearance in late summer and fall after the moult. As the coat becomes brittle from exposure, the black ends wear off to account for the typical faded appearance of the spring coat.

Fig. 7. Ewe (in the lead) with a lamb and two yearlings.
(Photo by Mr. W. R. Weber)

Fig. 8. Adult rams with adult ewe.
(Photo by Mr. W. R. Weber)

In the Sheep River study area adult rams and juveniles of both sexes begin to moult about the middle of May. The moult is an extended process that gives sheep a scruffy appearance for a month or more. Generally, hair first detaches from the back, sides and shoulders and later from the neck and rump. The earliest a complete summer coat has been observed was June 23, 1956 on a yearling ram. By the middle of July all yearlings, two-year-olds and adult rams have full summer pelage. Nursing ewes are generally two weeks slower in shedding their winter coats. Shaggy coats were observed as late as August 22. Hair and "underfur" grows slowly throughout the summer and fall so that the winter pelage becomes apparent by late September (Green, 1949). Lambs are born with a woolly pelage that is shed in the early fall and replaced with a pelage that is similar to the adult (Cowan, 1940).

The growth rate of the bighorn is rapid during the first summer, then the sexes begin to differentiate as to size, i.e., rams grow at a more rapid rate than ewes. Lambs are small enough to stand under their mothers when newly born and may double their birth weight in the first month (Fig. 7). By one year some rams may weigh as much as 100 pounds. Ewes may take as long as two years to attain the same weight (Seton, 1927).

Two year rams are slightly larger than adult ewes and at five or six years may weigh from 250 to 325 pounds (Honess and Frost, 1942). Adult ewes weigh from 125 to 175 pounds (Green, 1949). The shoulder height of an adult ewe is around 35 inches and the shoulder height of an adult ram is close to 40 inches (Fig. 8). Table III gives some weights and measurements of bighorns collected on the study area.

Table III. Some weights and measurements of nine Alberta bighorn sheep.

Coll. No.	Date	Sex	Age	Measurements in inches					Wt. (lbs.)
				Tot. l.	Tail	H. ft.	Ear	Shoulder	
41A	May 10/56	M.	fetus	-	-	-	-	-	9
25	July 15/55	M.	6 wks.	33.5	2	10.5	3.25	17	19
40A	Dec./55	F.	7 mos.	43	3.5	14	3.75	28	45 (emaciated)
43	May 26/56	M.	1	52	4	15	4	33	90
38	Sept. 7/55	M.	1+	52	4	15.5	4	31	-
37	Sept. 7/55	M.	1+	55	4	16.5	4.5	38.5	-
36	Sept. 3/55	M	2+	58	4	17	4	39	-
41	May 10/56	F.	4	56	4	15	4	35	163 (gravid)
39	Sept. 8/55	F.	4+	53	3.5	15.5	4	35	-

Fig. 9. Adult ewe (left) and 15 month old ram (right) showing similar horn conformation.

Fig. 10. Adult ewes in summer pelage. (Photo by Mr. L. Leacock)

Horns reveal both the age and the sex of the bighorn. Horn growth is rapid for three or four summers in both sexes, then the annual increment becomes progressively less until the age of eight or ten years. By this time the annual increment is so slight it is sometimes impossible to distinguish the growth rings. Cowan (1940) suggests that cessation of horn growth is primarily a result of physiological influences associated with the breeding season. However, a horn annulus is laid down by both sexes and all ages including those prior to breeding age which would suggest that breeding season influence is not so great. Food shortage during the lean months of January and February is a more likely causative factor for the annual sulcus.

During their first summer young rams and ewes are indistinguishable in the field. The length of horn at seven months is from 1/2 inch to 2 inches with little more growth until spring. The horns of yearling rams are heavier at the base. With experience in the field this can be observed in side view. However, from front view the horns closely resemble those of adult ewes (Fig. 9). The horns of the yearling ewe appear as short straight spikes becoming slightly recurved and more upswept to a length of 9 to 12 inches at maturity (Fig. 10). The horns of the male continue to grow and curve back, down and forward becoming more massive with each annual increment (Figs. 11

Fig. 11. Rams having different stages of horn growth from two to six years (Photo by Dr. R. B. Miller).

Fig. 12. Four rams and a ewe showing rear view of horns (Photo by Mr. W. R. Weber).

and 12). The longest ram horn recorded measured 49.5 inches outside circumference (Boone and Crockett, 1952).

Broomed horns, i.e., broken or worn horn tips, were occasionally observed on yearlings of both sexes and some adult ewes. Rams over five years of age almost invariably had one or both horns broomed (Table IV). Many of the broomed horns observed on ram skulls had their tips broken off and the ends that remained were shattered. The ends of the horns on other ram skulls were blunt and worn smooth. Back and shoulder rubbing with the horns may contribute to worn tips. Young rams have been observed in the spring scratching the bases of their horns on trees and rocks and in some instances the tips were being rubbed at the same time. The fact that young sheep and adult ewes sometimes have broken horn tips may be a result of being struck by the horns of the larger rams. A certain amount of horn abrasion probably occurs when large rams bed with their necks outstretched so that one or both horns come in contact with the ground. There seems little doubt that horn tips are broken off in battles between the rams during the rut. Certainly the horns are struck with considerable force, since some of the ram horns examined had large portions chipped from along the frontal plane. A five or six-year-old ram may have a nearly complete curl prior to the rut, then, during the rut an off centre head-first collision with another ram could easily result in a broken horn.

Table IV. Frequency of brooming in bighorn ram horns.

Age	No. of Horns	% Broomed
3	31	5
4	39	18
5	20	50
6	23	64
7	16	81
8	9	77
9	7	100

The core of the horn is an extension of the frontal bone and it serves to strengthen the horn. The vascular tip of the bony core contributes to horn growth by depositing a slightly porous cornified material on the central portion of the horny sheath. The bulk of the horn sheath is formed by layers of keratinized material from the epidermis. Growth of the bony core and horn base is negligible after four years (Table V). However, the growth of the horn sheath is continuous (Fig. 13).

Fig. 13. Horn growth of Rocky Mountain Bighorn rams.

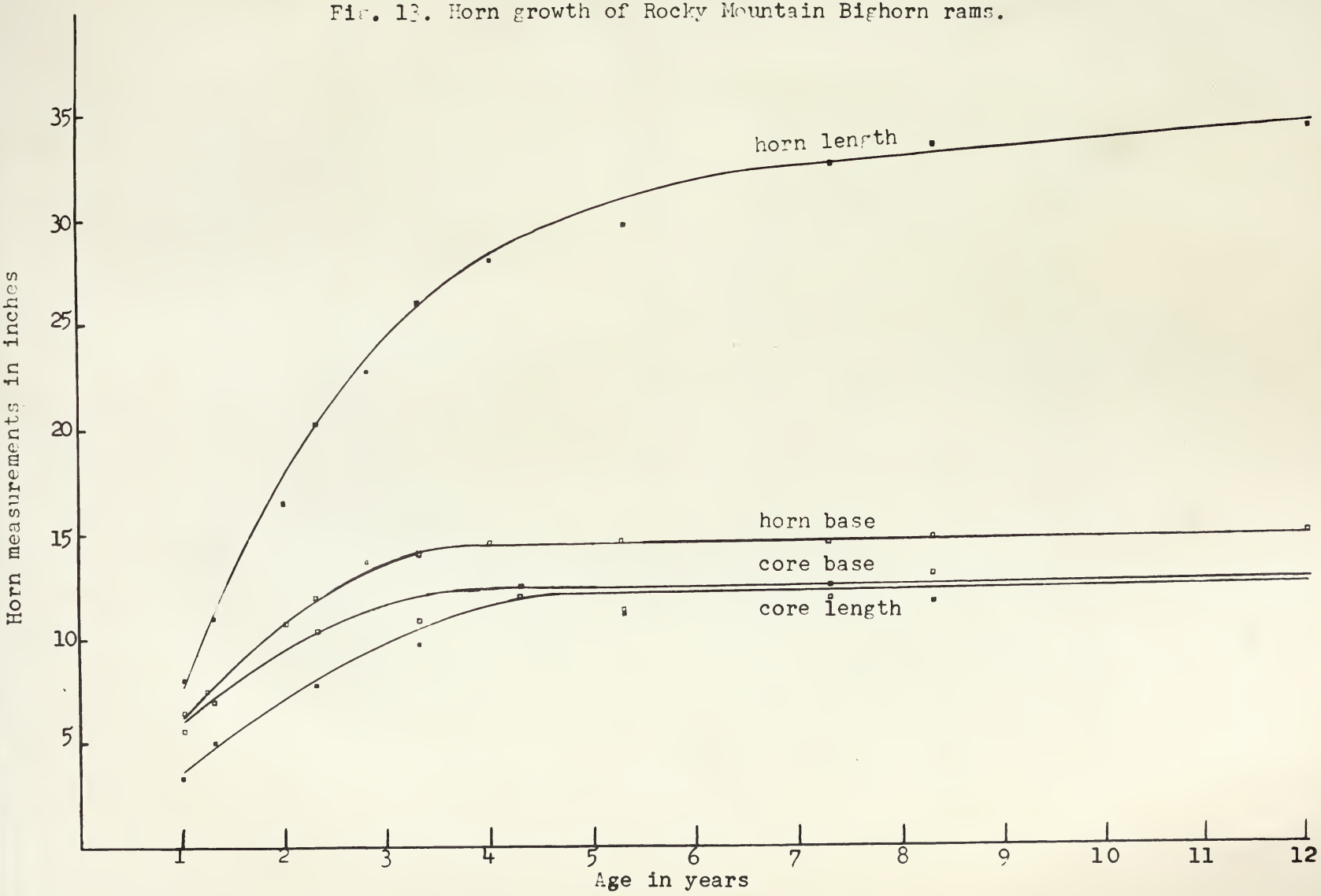
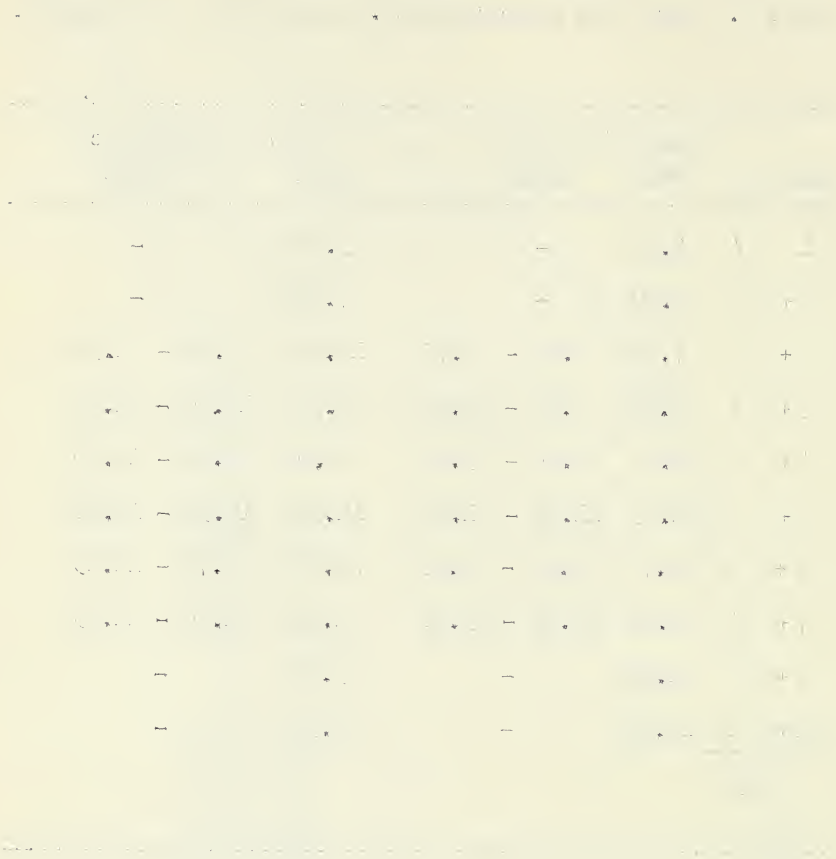


Table V. Horn core measurements of rams aged 1 to 11 years.

Age	N	Length in inches Mean	Range	Base Circumference Mean	Range
1	4	3.25	-	5.50	-
1+	2	5.00	-	7.00	-
2+	8	7.75	6.00 - 8.75	10.25	9.00 - 11.50
3+	5	9.50	8.25 - 11.00	10.50	10.00 - 11.00
4+	4	12.50	10.00 - 13.00	12.00	10.50 - 12.50
5+	2	11.25	11.00 - 11.50	11.50	10.50 - 12.00
6+	4	11.75	11.00 - 12.25	12.00	11.75 - 12.25
7+	4	12.50	12.00 - 13.00	11.25	11.00 - 11.25
8+	1	11.50	-	13.00	-
11+	1	12.00	-	11.50	-
	35				



SIZE, AGE AND SEX COMPOSITION OF THE BAND

During spring, summer and early fall ewes and immature animals range most commonly in groups of two to nine. Bands are loosely associated and there are frequent fluctuations in herd composition as numerous combinations of sexes and ages are formed, broken up and formed again. The mature rams range in groups of 2 to 14 and remain separate from the other sheep until the rut. During the winter and early spring both sexes and all age groups are seen together. In the late spring mature rams were observed on the same range and near other sheep. However, they were seldom seen to mix. Adult rams were frequently observed on wintering areas that were little used by ewes and immature animals. On one occasion a group of yearling rams attempted to join four large rams. The latter bolted and were found next morning in a valley four miles south of their original location.

Of 440 observations made in this study the group size varied from 1 to 40 (Table VI).

Table VI. Bighorn aggregations.

Group Size:	Singles	2-9	10-19	20-29	30-40
No. of obs.:	72	259	79	25	5

Twenty of the 72 singles were adult ewes and 7 were adult rams. The remainder were 33 yearling males, 10 yearling females and 2 unidentified. The herd size averaged 8.9 from May until September in 1955 and 8.0 for the same period in 1956. Smith (1954) noted that Baillie-Grohman reported the average flock size in the Rocky Mountains in 1882 averaged about eight. The comparison indicates what Smith calls the "constant degree of gregariousness." The composition of the Sheep River herd over a period of four years is given in Table VII.

Table VII. The size, age and sex composition of the Sheep River sheep herd from 1955 to 1958.

	Adult ewes	Two yr. ewes	Yearling ewes	Adult rams	Two yr. rams	Yearling rams	Total
May 1955	24	5	9	4	2	13	57
May 1956	22	9	10	5	4	7	57
May 1957	23	9	7	9	12	9	68
Jan. 1958	26	4	*$\frac{21}{2}$	7	7	*$\frac{21}{2}$	65

*Not sexed.

In the spring of 1955 there was a total of 57 sheep on the winter range. The aggregate summer counts of ewes and lambs gave a ewe-lamb ratio of 1:0.78. With this ratio the 24 ewes would theoretically have 19 lambs. During the hunting season of 1955 eleven rams, of which nine were yearlings, and one ewe were killed leaving a total of 64 sheep. If each of the remaining sheep had returned to the winter range and there had been no natural mortality, there would have been 28 adult ewes, 9 two-year ewes, 4 adult rams, 4 two-year rams and 19 yearlings or a total of 64 sheep. The spring census in 1956 showed a reduction of six adult ewes and two yearlings and an increase of one adult ram giving a total of 57 sheep. In May, 1956 one adult ewe and one yearling ram were shot for examination. During the summer of 1956 the ewe lamb ratio from aggregate counts was 1: 0.83. With this ratio the 21 ewes would theoretically then have 17 lambs. In the hunting season of 1956 legislation permitted only those rams with a 3/4 curl or larger to be shot and no rams were killed on the study area. In January, 1957 a 2+* ram was collected for examination. Prior to the spring census of 1957 a yearling ram was found dead on the winter range. Again if each sheep had returned to the winter range and no more mortality had occurred there would have been 30 adult ewes, 10 two-year ewes, 8 adult rams, 6 two-year rams and

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*The symbol + applies to animals that are from three to six months older than their last birth date, i.e., June or July.

16 yearlings or a total of 70 sheep. The census showed a reduction of seven ewes and one two-year ewe and an increase of one adult ram and six two-year rams yielding a total of 69 sheep. During the summer of 1957 the ewe-lamb ratio from aggregate counts was 1:0.90. With this ratio the 23 ewes would theoretically have 21 lambs. One adult ram was killed on the study area during the fall hunting season leaving a total population of 89 sheep composed of 32 ewes, 7 two-year ewes, 20 adult rams, 9 two-year rams and 21 yearlings. The census this year showed a reduction of six adult ewes, three two-year ewes, 13 adult rams and two two-year rams. In three years a total of 19 adult ewes, 10 adult rams, 3 two-year ewes and 2 yearlings had unaccountably disappeared from the herd. Natural mortality on the winter range of the study area could account, perhaps, for half of this reduction; the balance appear to have moved to other ranges. In 1956 and 1957 there was a total influx of two adult rams and six two-year rams which would indicate that the rams winter on different ranges from year to year. The fluctuating numbers of rams appear to have no effect on the numbers of ewes and yearlings, i.e., the latter have appeared on the winter range in relatively constant numbers for the past four years. It appears that the range will support a certain number of ewes and yearlings. These numbers are independent of the rams.

Table VIII is a list of ram-ewe and ewe-lamb ratios of the Sheep River herd from 1955 to 1958. The ratios are compared to those of a herd in Banff Park. The Park observations were made from June 2 to September 16, 1956 at an artificial salt lick near Aylmer Mountain lookout. The observer was Mr. Norman Titherington who had been lookout man on Aylmer Mountain for eight years. The ratios were determined from his figures based on 103 observations of a herd of 97 head. The ram-ewe ratios were determined from actual numbers of adult rams and adult ewes. The ewe-lamb ratios for the Sheep River herd were determined from the aggregate number of adult ewes and lambs seen each summer beginning on the first of July. The ewe-lamb ratio for the Banff Park herd is based on actual numbers.

Table VIII. Ram-ewe and ewe-lamb ratios of the Sheep River herd from 1955 to 1958 compared to ratios of a herd in Banff Park in 1956.

	Ram-ewe	Ewe-lamb
Sheep River, 1955	1:6.0	1:0.78
Sheep River, 1956	1:4.4	1:0.83
Banff Park, 1956	1:0.9	1:0.84
Sheep River, 1957	1:3.2	1:0.90

The table demonstrates that lamb production remains relatively constant regardless of ram-ewe ratios.

Ewe-yearling ratios can be determined from spring censuses, but on the study area it is believed that since not all the ewes in the herd are represented on the winter range each year a very high yearling to ewe ratio is obtained. Aggregate counts were not useful for ewe-yearling ratios in this study since yearlings were seen more often than ewes even after the lambing period. Consequently the ratio of yearlings to ewes was unreasonably high. Yearling rams appeared to wander a great deal and were seen more often than yearling ewes during each summer. Because of this the aggregate counts resulted in an unbalanced sex ratio. Spring censuses revealed that there was no significant difference between the numbers of yearling males and yearling females prior to each of the summer counts. The sex ratios of the two-year-old sheep were irregular in both aggregate counts and spring censuses due to the wandering habits of the rams. Aggregate counts were used with some degree of accuracy only in determining ewe-lamb ratios.

SEASONAL AND DAILY MOVEMENTS OF BIGHORN SHEEP

During the winter, sheep in the study area are confined mostly to the foothills along the Sheep River canyon. In the spring there is a definite shift to summer range, which is mostly above timberline. This type of movement is common to several bands of bighorn sheep along the front range of the East Slopes in Alberta. The rivers provide steep shale passageways between summer and winter ranges. On some shale formations there are natural mineral licks that have a strong attraction for bighorn. As a rule sheep can be found near the front range along river systems that have cut through Wapiabi, Bighorn and Blackstone formations. Some examples of where this occurs are along the Sheep, North Sheep, Ram, Blackstone, and Bighorn Rivers. The sheep in higher ranges, such as in the Parks, show no well defined seasonal movements to and from winter and summer ranges (Green, 1949).

The sheep showing definite seasonal movements are influenced chiefly by the weather. Since their diet on the high summer ranges consists mostly of low growing herbage, only a few inches of snow causes them to descend to their winter range. During the late fall snowstorm in 1954 one rancher observed 72 sheep on the move toward winter range for a distance of 14 miles along the Sheep River. Again on May 24, 1955 a late

spring snowstorm resulted in 17 ewes returning to their winter range from the lower fringe of their summer range and lambing grounds.

Several unsuccessful attempts were made to band or mark sheep in an effort to determine the extent of their seasonal movements. In spite of the banding failure, it was possible to recognize some individual sheep by body color or by horn differences, such as broken tips, unusual flare or the different horn sizes on rams of different ages. The balance of the discussion is based largely on observations of this sort.

The spring movement from the lower altitudes towards the higher summer range is leisurely. If favorable weather prevails before the period of lambing the ewes and some of the yearlings are the first to depart. Their progress is governed by the rate of the regressing snowline. The areas utilized at this time for bedding and feeding are considered as intermediate range. The adult rams in the study area are among the last to leave for the summer range. A group of seven adult rams remained on the winter range as late as July 6, 1957. Other adult rams were seen on their way to summer range on June 11 and June 23, 1956.

Sheep that were observed on the move along the migration routes showed extreme caution when crossing flats or entering timbered areas. The migration routes taken by different

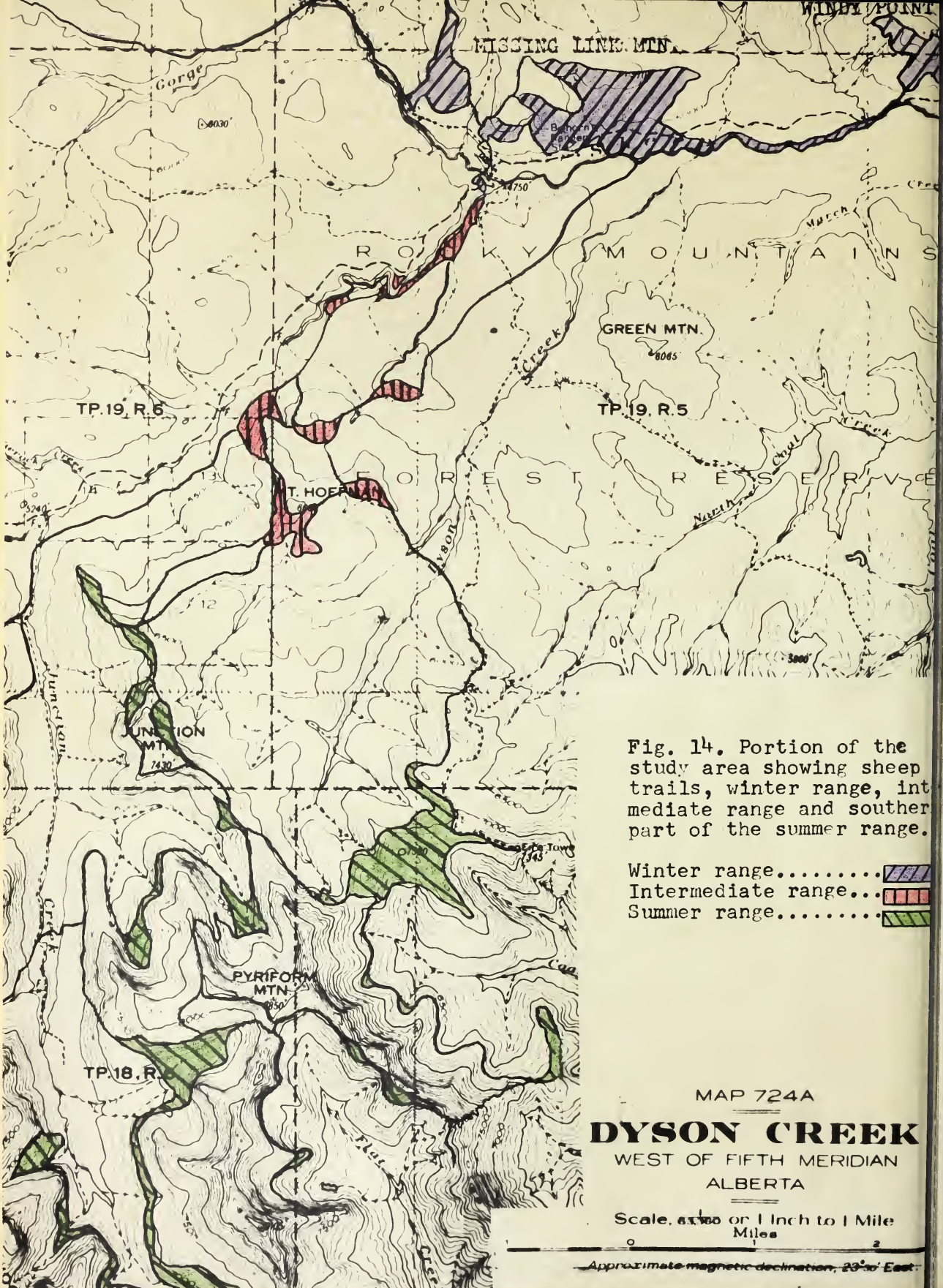

Fig. 14. Portion of the study area showing sheep trails, winter range, intermediate range and southern part of the summer range.

Winter range.....
Intermediate range...
Summer range.....

MAP 724A

DYSON CREEK

WEST OF FIFTH MERIDIAN

ALBERTA

Scale, 4 inches or 1 Inch to 1 Mile

Miles 0 1 2

Approximate magnetic declination, 23° East

groups of sheep generally followed the contours or a line of least resistance and varied in length from 8 to 25 miles (Fig. 14).

During the late fall or early winter rams seem to wander from one winter range to the next, depending on weather conditions. During a mild spell in Mid-December, 1956, Mr. W. T. Balmer, Forest Ranger, observed two adult rams coming from the winter range of the North Sheep River to the winter range of the study area. The distance between the two ranges is approximately ten miles. Yearly counts give considerable evidence that rams winter on different ranges from year to year (see page 19). Earlier it was mentioned that yearlings and some ewes tend to return to the same winter range year after year and that some ewes are forced to winter elsewhere. This conclusion is supported by observations of Mr. H. Marshall, a trapper, who has been on the study area for several years. He has observed sheep wintering from time to time on the high windswept slopes of Burns Mt., i.e., the normal summer range of the sheep on the study area.

The daily feeding and bedding habits follow no particular schedule. In fact, daily activity is erratic and unpredictable. Most of a band may be observed feeding while a few remain bedded, or most may be bedded while a few individuals continue to graze. Generally speaking, bedding occurs after morning and midday feeding and again at night. However, during the spring, sheep may be observed feeding most of the day and bedding only at night. Usually

a little time and care are taken by sheep in pawing out hollows in shale or scree for night beds which are usually near or on an escarpment. Day beds are chosen at random and made with a few strokes of a forefoot. Groups of three or more sheep were rarely seen bedded so that all were facing the same direction. Probably this arrangement is fortuitous. However, it serves as an effective protective measure.

Summer weather seems to have little effect on the daily routine of the bighorn. Sheep were observed bedded and grazing on an exposed slope during a hailstorm and showed no apparent discomfort. Again, sheep were often seen apparently resting comfortably, yet exposed to the hot sun in the middle of the day, although on extremely hot days they would take shelter occasionally in aspens or conifers.

Fig. 15. South facing slope of Missing Link Mountain that is utilized for winter range.

FEEDING HABITS

Forage Studies. It is generally accepted that in the north temperate zone the number of big game mammals that an area will produce and maintain depends largely upon the condition of the winter range. The bighorn presents a special problem since it requires winter forage in close association with escape terrain. On the Sheep River approximately 350 acres of grassland associated with escape terrain are utilized by an average of 62 sheep each winter. Thirty-five acres of the grassland form a hay field that has been mowed, plowed, planted with brome and timothy and mowed again for several years. The balance of the range includes the south facing slopes of Missing Link (Fig. 15) and Windy Point Mountains and an adjoining strip along the Sheep River. Those areas that are very close to escape terrain that are first made snow-free by wind or sun are grazed bare by bighorns, but generally the range shows evidence of only moderate grazing.

As a rule sheep are constantly on the move while feeding. Areas up to a half a mile across may be covered before a meal is completed. This type of feeding makes the different food plant species readily available. In the spring sheep were observed grazing for most of the day. As the season progressed feeding became more and more interrupted by rest periods until the feeding periods became confined mostly to morning, midday and

evening. The quantity consumed for a meal by one four-year-old ewe (coll. no. 41) and a one-year-old ram (coll. no. 43) measured eight and seven pounds respectively.

Bighorns were observed either grazing and/or browsing on 216 occasions. If one or a group of animals was seen both grazing and browsing it was recorded as one grazing and one browsing observation. Table IX gives the number of grazing and browsing observations for the spring and summer months of 1955 and 1956.

Table IX. Numbers of grazing and browsing observations of bighorn sheep, 1955-56.

	Grazing	Browsing
April - May	90 (86.5%)	14 (13.5%)
June - July	63 (75.0%)	21 (25.0%)
August - September	20 (71.4%)	8 (28.6%)

It is apparent that the bighorn is primarily a grazing animal with a tendency to browse more in the late summer.

The plants utilized by the sheep were determined at approximately every fifth feeding observation, i.e., the feeding areas were examined after the animal (s) had departed.

The different plant species grazed or browsed were recorded. It was then possible to draw up a list of food preferences. The plants preferred were separated into four groups based on the numbers of times utilized, i.e., high, moderate, moderately low and low (Table X). The frequency of the preferred plants that appeared in the transects described earlier is also given in Table X.

Generally there seems to be a direct relationship between preference and frequency, except for the browse species and this is due to the transects not being located on browse areas. It may be assumed then, that most of the plants utilized are readily available. From this assumption the food preferences of the bighorn may be used as a quantitative estimate of the plants they consume. If the values 10%, 7%, 4% and 3% are substituted for the symbols H, M, ML and L respectively in Table X they conveniently add up to 100% for each column. An estimate can then be given of the percentage of grasses, sedges, forbs and browse that occur in the bighorn diet (Table XI).

Table X. Preference rating and availability of plants utilized by bighorn (1955-56). (The symbols H, M, ML and L are high, moderate, moderately low and low respectively and they represent the numbers of times each plant was utilized.)

	Spring			Summer		
Plant Species	Apr.-May	June	% Frequency in transects	July	Aug.-Sept.	% Frequency in transects
Carex spp.	H	ML	6.7	H	M	9.6
Agropyron spp.	M	-	8.0	M	M	3.5
Koeleria cristata	M	M	11.6	L	ML	7.6
Bromus spp.	ML	L	1.4	ML	ML	1.9
Festuca scabrella	M	M	2.8	ML	-	3.0
Phleum pratense	ML	L	1.0	-	-	-
Agrostis sp.	-	L	-	-	-	-
Elymus innovatus	L	L	0.1	-	ML	3.0
Arctostaphylos uva-ursi	L	-	-	L	-	3.6
Equisetum sp.	-	ML	-	L	-	-
Astragalus spp.	ML	ML	1.5	M	H	0.6
Oxytropis spp.	L	ML	2.2	H	M	3.7
Hedysarum spp.	L	ML	-	M	H	1.7
Agoseris sp.	-	L	0.6	L	-	2.0
Delphinium sp.	-	ML	-	M	M	-
Cirsium sp.	-	ML	-	M	M	-

Table X. (Continued)

Plant Species	Spring			Summer		
	Apr.-May	June	% Frequency in transects	July	Aug.-Sept.	% Frequency in transects
Potentilla spp.	L	L	0.3	-	-	3.7
Pulsatilla ludoviciana	L	L	-	-	-	0.4
Dodecatheon cusicki	ML	L	-	-	-	-
Fragaria glauca	ML	L	-	-	-	1.4
Smilacina sp.	L	-	-	-	-	0.2
Zygadenus sp.	ML	-	-	-	-	-
Castilleja sp.	-	L	-	ML	-	-
Populus tremuloides	ML	ML	-	ML	H	-
Shepherdia canadensis	L	L	-	-	-	-
Eleagnus commutata	-	L	0.1	-	-	-
Ribes setosum	ML	ML	0.1	ML	H	0.2
Salix spp.	ML	ML	0.1	ML	H	0.2
Picea glauca	L	ML	-	L	-	-
Rosa acicularis	L	L	2.1	L	-	0.3
Potentilla fruticosa	-	L	1.2	-	-	2.6
Amelanchier alnifolia	L	-	0.8	-	-	-
Alnus tenuifolia	-	-	-	-	L	-
Sambucus glauca	-	-	-	L	-	-

Table XI. Percentages of grasses, sedges, forbs and browse consumed by bighorns in spring and summer, 1956-57.

	Apr.-May	June	July	Aug.-Sept.
Grasses and sedges	42	30	28	32
Forbs	34	42	47	34
Browse	24	28	25	34

The results correspond fairly closely to the grazing and browsing observations of Table IX. The table serves to show that forbs are the most important forage items in the summer diet of the bighorn.

Stomach samples were collected from six sheep, one in January, 1957, two in May, 1955 and three in September, 1955. The samples were strained through 1/4" mesh screens. Approximately half the material retained could be identified. The identifiable remains were distinguished as grasses, sedges, forbs or browse. The results are given in Table XII.

XII. Percentages of grasses, sedges, forbs and browse in six bighorn sheep stomach samples - Sheep River.

Date	Coll. No.	Age	Sex	Grasses and sedges	Forbs	Browse
Sept. 3/55	36	2	M.	21%	72%	7%
Sept. 7/55	37	1	M.	35%	56%	9%
Sept. 8/55	39	4	F.	32%	52%	16%
May 10/56	41	4	F.	100%	-	-
May 26/56	43	1	M.	92%	8%	-
Jan. 7/57	52	2	M.	75%	25%	-

The stomach samples offer some support to the earlier data on feeding observations by showing the contrast between spring and late summer food preferences. Some of the forbs and browse species from the stomach samples were identified by Dr. E. H. Moss of the Botany Department, University of Alberta. The results are given in Table XIII.

Table XIII. Forb and browse species that occurred in five bighorn sheep stomach samples.

Coll. No.	Forbs	Browse
36	Hedysarum sp. (fruits and foliage)	Salix spp. (twigs and leaves)
	Gill fungus	Potentilla fruticosa (leafage)
	Moss (trace)	
37	Potentilla spp. (leafage)	Salix spp. (Twigs and leaves)
	Fragaria (sp. (leafage)	Populus sp. (leafage)
	Astragalus sp. (fruits)	Symphoricarpos sp.
	Antennaria sp. (trace of leaves)	Sambucus glauca (trace)
	Ledum sp. (trace)	
	Mosses (trace)	
39	Gill fungus	Salix spp. (leafage)
		Populus sp. (leafage)
		Abies sp. (seed scale)
		Amelanchier sp. (twigs)
43	Fragaria sp. (leafage)	Rosa sp. (twigs and leaves)
	Potentilla sp. (leafage)	
52	Artemesia frigida	

In April and May the diet of the bighorn is largely the new shoots of grasses and sedges that first appear on the winter range. As these plants ripen they become dry and less palatable. The sheep then drift to their summer range to feed on the later emerging plants. In June and July forbs are most utilized, preferably legumes, thistle (Cirsium sp.) and larkspur (Delphinium sp.). Browsing of aspen (Populus tremuloides), gooseberry (Ribes spp.) and willow (Salix spp.) is continuous throughout the season and becomes most apparent in the late summer. The main diet of the bighorn is low growing herbage.

Mineral Requirements. Natural mineral licks possess a special attraction for ungulates. Along the Sheep River canyon there are several mineral exposures which are used intensively as licks during the summer and fall by ewes and immature animals. Generally speaking every 10 to 14 days individuals return to utilize the licks. The mineral exposures are referred to by geologists as silvery grey weathering and it is believed that the minerals are leached from the glacial overburden onto the shale. The same type of weathering has been reported on the Bighorn, Sulphur, Smoky, Ram and North Sheep Rivers. Crystals of a mineral exposure from along the Sheep River were examined by Mr. C. E. Noble, Provincial Analyst, and were found to contain 9.6% NaCl and 26.9% $MgSO_4 \cdot 7H_2O$.

Possibly the sheep on the study area were seeking the NaCl, since their salting habits on the winter range were entirely confined to stock salt placed in the ranger's pasture for his horses. Herbivores may tend to be sodium deficient in their electrolyte balance due to the low amounts of sodium that occur in their forage. (Morrison, 1956). Some authorities claim that phosphorous and sodium are the essential elements. However, Cowan and Brink (1949) conclude sodium chloride and phosphorous are not necessarily the essential elements and that trace elements may well be the critical constituents in natural licks.

Fig. 16. Rams pursuing ewe apparently in oestrus. (Photo by Miss P. J. Low)

BREEDING AND LAMBING

Judging from observations on times of lambing and a known gestation period of 180 days (Honess and Frost, 1942), the rut or breeding season on the study area extends from the end of November until the middle of January. According to Mr. W. T. Balmer, the peak of the breeding season on the study area is in mid-December. Up to 1957 the study period had ended prior to the rut so that actual breeding behaviour was not observed. However, part of the breeding behaviour at the end of the rut was observed on January 26, 1958. Breeding behaviour has been described by several authors (Honess and Frost, 1942, Couey, 1950, Smith, 1954 and Russo, 1956). Usually one ewe in a group is in oestrus at one time. During this period a ram singles her out from the flock and a great chase begins with one or more rams joining in (Fig. 16). The oldest and largest ram attempts to keep the younger rams away from the ewe, but is not always successful. Copulation takes only a few seconds and ewes may be served by several different rams during one of these melees.

Each year about the middle of May adult ewes begin leaving the winter range for the lambing grounds. On June 6, 1955, three ewes and two very young lambs were observed above timberline on Song-allee-she Mountain. By June 22, 1955, seventeen different ewes had been observed and nine were accompanied by

lambs. On July 11, 1956, twelve different ewes were observed and nine were accompanied by lambs. On July 11, 1957, fifteen ewes and fifteen lambs were observed in the Sheep River canyon. It was concluded that the lambing period on the study area extends from the last week in May until the middle of July.

On two occasions it was believed that ewes had been observed with twins, but in each case there was a possibility that the extra lamb belonged to another ewe. Ewes were sometimes observed grazing or salting a quarter of a mile away from their lambs. A temporarily abandoned lamb was usually left in the company of other ewes and lambs and on such occasions an observer could easily mistake the lamb for a twin.

It is generally believed (Honess and Frost, 1942, Spencer, 1943, Smith, 1954) that bighorn ewes do not breed until they are two and a half years old, although one has been successfully bred at one and a half years in captivity (Deming, 1955). No two-year ewes were observed with lambs during this study. Most observers believe that rams also reach sexual maturity at two and a half years (Spencer, 1943). Rams of all ages exhibit some sort of breeding behaviour the year round. In order to determine what ages were fertile, sections of testes from rams aged one, one and a half and two and a half were examined for spermatogenesis. These rams were collected on May 26, 1956, Sept. 7, 1955 and Jan. 7, 1957, respectively. Since spermatogenesis

was evident in the seminiferous tubules of the latter specimen only, it was concluded that rams may reach sexual maturity prior to their third year.

MORTALITY

Old Age. Cowan (1940) states that "the ultimate maximum age in sheep is limited largely by the life span of the teeth." One hundred rams skulls from the Luxton collection and the study area and 18 ewe skulls from the study area were examined for cheek tooth development and wear. Tooth succession followed closely the description given by Cowan (1940); all sheep five years or over had complete permanent dentition (Table XIV). Surface wear of teeth first appeared in a few four-year rams. However, tooth wear was more apparent in rams over seven years (Table XIV). Four of the oldest rams examined were eleven to twelve years old. As the tooth surface wears away the tooth pushes outward from the socket becoming shorter with age (Murie, 1944). This is confirmed by measurements of the second upper molars of 13 ewe skulls that were found on the study area (Table XV). Only two ewes had cheek teeth that were badly worn. Nine ewes with slightly worn cheek teeth were estimated to be in the seven- and eight-year-old classes. The situation seems to be very similar to that described by Murie (1944). He placed ewes of nine years or over in the old age class, and his data on longevity strongly suggested that ewes are shorter lived than rams. He found that few ewes lived beyond ten years while many rams reached the twelve year class.

It is well known among sheep breeders that broken mouth can occur in domestic sheep at an early age depending on the range conditions. Wherever rock and gravel occur on certain ranges, the incisors of the domestic sheep become separated, chipped and broken. It is possible that ewes on the study area are subject to more incisor damage than rams because of their habbit of nibbling at the mineral deposits along the shale banks of the Sheep River in summer and fall. The rams, on the other hand, range near areas where soft earth licks are known to occur. Possibly the conditions of the incisors determines to some degree the relatively short life span of the ewes on the study area. Unfortunately, no conclusive evidence of this could be found, since very few lower jaws were picked up that still retained incisors.

Table XIV. Tooth condition of 100 ram skulls from Luxton collection and the study area.

Age	N	Percentage with complete dentition	Percentage showing surface wear
1+	10	0	0
2+	11	0	0
3+	20	35	0
4+	23	86	14
5+	10	100	10
6+	9	100	33
7+	5	100	60
8+	5	100	40
9+ and over	7	100	100

Table XV. Lengths of second upper molars from 13 bighorn ewe skulls.

Coll. No.	Estimated Age								
	2 yrs.	3 yrs.	4 yrs.	5 yrs.	6 yrs.	7 yrs.	8 yrs.	9 yrs.	10 yrs.
1						48 mm.			
2							47 mm.		
8									43 mm.
9	50 mm.								
10						48 mm.			
12						48 mm.			
15									43 mm.
18						48 mm.			
19						48 mm.			
40	53 mm.								
53						48 mm.			
54		50 mm.							
57							46 mm.		

Predation. In the summer months sheep usually stay close to precipitous terrain and as a result are seldom vulnerable to a predator's running attack. On the Sheep River wintering grounds sheep are more subject to predation due to winter conditions

and less accessible escape terrain. Remains of several sheep were found on the study area (Table XVI), but as these were largely portions of skeletons and carcasses that were beyond autopsy, the toll taken by predators is unknown. Nearly all age classes were found; most were from the youngest and oldest age groups. The remains of twelve sheep were found in the bottoms of ravines and the remains of six other sheep were found at a considerable distance from escape terrain. The possibility of predation could not be eliminated in any one of the situations. Those that were found in the ravines may have been weakened sheep that had succumbed to exhaustion in deep snow; the others may have been dragged by carrion feeders or poachers from the original death site.

Table XVI. Remains of sheep believed to have died from natural causes (classified as to age and sex).

	Age in Years												
Sex	Lamb	1	2	3	4	5	6	7	8	9	10	?	Total
Ewe	1		3	2		1		6	3		2		18
Ram	1	4					1	1			1		8
?	1	4										5	10
Total	3	8	3	2	0	1	1	7	3	0	3	5	36

The cougar, because of its agility and size, combined with its habit of seeking prey in rough terrain, is an important sheep predator. In recent years rangers, trappers and stock riders in the district have seen a total of four cougars in the study area. Although never abundant, cougars are certainly capable of diminishing big game numbers. Green (1949) on two occasions found where sheep had been killed by cougar; he also observed three

unsuccessful attempts by cougar to catch sheep. Another observation was made by the late Dr. J. A. Allan of the University Geology Department who had the rare experience of observing a cougar kill a mountain sheep on the highway near Exshaw. It is believed that cougar predation on sheep in the study area would be buffered by mule deer, since the latter are more abundant and the cougars' preference for deer is well known (Young and Goldman, 1946).

Coyotes, bears, lynx and wolverine may be considered as occasional sheep predators, although very little incriminating evidence showed up in this study. The district ranger described seeing two coyotes kill an adult ewe by forcing her over the wall of the Sheep River canyon. The incident took place in the winter of 1953. One coyote chased the ewe through the ranger's yard from the slopes of Missing Link Mountain while the other coyote blocked an escape route leading into the canyon, so that the ewe was forced over the edge.

Just prior to the study period large numbers of coyotes were poisoned during the rabies control campaign and, until recently, coyotes were seldom seen on the study area. On June 1, 1955 two coyotes were observed converging on a small group of deer. The deer bounded up a hill and the coyotes quickly gave up the chase. Immediately after the chase was over the indifference that was shown by one species for the other was remarkable. The deer began grazing on the hillside while one coyote sat and scratched and the other wandered off through an aspen grove. The same sort of indifference was observed again when a young grizzly bear lost out in a chase, first with five sheep, then with a cow elk an hour

later. After being chased part way up a mountain, in each case, the sheep and the elk started to graze while the bear lumbered along only a few hundred yards below feeding on legume roots.

During the study period snowshoe hares were noticeably scarce, while sight records and tracks of lynx were relatively common. This unusual lynx-hare relationship perhaps explains the following case of lynx predation on mule deer. During the latter part of the winter in 1956, R. C. Hill, the assistant ranger, found a young deer dead and partly devoured, lying along the road where it passes through the bighorn winter range. The tracks in the snow showed where the deer had run out of some trees, down a ravine and across the road to where it had dropped. The only other signs in the snow were a set of lynx tracks leading away from the carcass. Apparently the lynx had pounced on the deer's back and rode it until it had collapsed. This type of lynx predation on big game is considered exceptional. The possibility of bighorn sheep being killed under such conditions should not be overlooked.

Wolverine sign was observed on three occasions on bighorn summer range. The amount of wolverine predation on sheep in summer or winter is unknown.

Wolf predation on the bighorn in the study area is unlikely. Only one wolf has been observed on the study area since the Biological Station opened in 1950.

The golden eagle is both a predator and a carrion eater (Arnold, 1954), and, like most widely ranging species, its food varies from place to place depending on availability. Eagles are known to harass a wide variety of animals ranging in size from ducks to grizzly bears (Murie, 1944). During the entire study period eagles were never seen to attack or molest any of the large game mammals, young or old. A golden eagle nest on the study area was kept under observation by Mr. D. A. Boag for the period May 5 to August 19, 1955. Food items are reported in the Alberta Biological Station Report No. 5, 1955. It was found that small rodents are the main food items of the nesting eagles (Table XVII). The eagles' territory extended from the bighorn wintering grounds to the fringe of the lambing grounds.

Table XVII. Food items found in golden eagle nest.

Species	Number
Citellus columbianus	68
Dendragapus obscurus	10
Citellus lateralis	3
Odocoileus hemionus	2
Lepus americanus	1
Mustela frenata	1
Neotoma cinerea	1
Thomomys talpoides	1
	87

In Wyoming, Honess and Frost (1942), observed an eagle's nest in the heart of the lambing grounds and found no remains of lamb or adult bighorns. Murie (1944) reported that no authentic case of an eagle killing a lamb came to his attention during a three-year intensive field study of Dall's sheep. It seems apparent then, that eagle predation on mountain sheep is negligible.

Hunting. Conclusive evidence of poaching on the study area was found on three occasions. One hunting party admitted they shot a ewe each fall for their camp meat supply. Although poaching may account only for small losses of sheep, it is felt that every limiting factor should be considered. Another small and unnecessary loss of sheep occurred pripr to the 3/4 curl legislation. That is, ewes were sometimes shot by hunters who had mistaken them for yearling rams. In the fall of 1953, three ewes were shot in error and turned into the ranger station. For three consecutive years one part-time trapper reported shooting a ewe for a yearling ram on the North Sheep River. Under the present hunting regulations this particular form of ewe mortality has come to an end.

Before 1956 legal sheep hunting on the study area removed a large portion of the young rams. Table XVIII gives

some idea of the relative ages and numbers of sheep that were being harvested by hunters in the study area prior to the 3/4 curl legislation.

Table XVIII. Sheep remains (horns and heads) left on the study area by legal sheep hunters.

	Age in years							
Sex	1+	2+	3+	4+	5+	6+	7+	8+
Male	6	9	1	1		1	2	2
Female				1				

Accidents. Various accidents have been reported by different authors. Deaths have resulted from falling off cliffs, snowslides, fighting and porcupine quills. Accidents are inevitable for a creature like the bighorn which frequents precipitous terrain. For example, a ewe was seen to injure her right hindleg, presumably on a rock, in her haste to cross the Sheep River, June 3, 1955. Her flight up the canyon wall was impaired by her limp so that she stumbled and almost fell into the river 100 feet below. Predation, poaching, deep snow and accidents account for a part of the steady drain of sheep numbers from the study area.

Parasites and Disease. Diseases and parasites are generally considered the major factors for bighorn mortality (Honess and Frost, 1942). It should be stressed that normal healthy sheep commonly harbour both internal and external parasites without noticeable harm. However, effects of infection and infestation may appear if there is prolonged exposure to adverse or over-crowded range conditions.

Fresh droppings from 28 bighorn were collected from May until September in 1956 and examined for endoparasites. All were nematodes. Three slides from each sample were examined.[1] Infection was considered medium if one larva could be seen within each field of the microscope, and light if one or two larvae appeared on each slide. The results are listed in Table XIX. Some of the larvae were identified tentatively as Protostrongylus sp. Fresh droppings from two yearling rams were sent to Dr. George Post, Director of the Game and Fish Laboratory at the University of Wyoming for positive identification of the endoparasites. He reported the larvae found in both samples were Protostrongylus stilesi Dickmans. He pointed out that various types of free-living nematode larvae frequently occur on droppings collected from the ground and one of these was also present in one of the samples. Couey (1950) found several dozen lungworm larvae in each field of the microscope when he examined bighorn droppings gathered in Montana. It would seem then, that the most heavily

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[1] A sedimentation method described by Smith, 1954, was used to examine the droppings.

Table XIX. Degree of nematode infection (some lungworm) in Sheep River bighorns, 1956.

Date	No.	Sex	Age	Nematode Infestation
May 17	26	M.	1	medium
May 17	27	M.	1	none
July 2	1	M.	1	light
July 2	2	F.	1	light
July 2	3	F.	1	none
July 5	4	F.	1	medium
July 5	5	F.	1	none
July 5	6	M.	1	light
July 7	7	F.	Adult	none
July 7	8	F.	Adult	none
July 11	8A	M.	2	light
July 12	9	M.	1	none
July 12	10	?	Lamb	none
July 12	11	F.	2	light
July 12	12	F.	Adult	medium
July 13	13	M.	1	none
	14	M.	1	medium
July 14	15	M.	2	light
July 23	16	F.	Adult	light
July 23	17	?	?	medium
July 23	18	?	?	medium
July 31	19	M.	1	light

Table XIX. (Continued)

Date	No.	Sex	Age	Nematode Infestation
Aug. 1	20	F.	1	light
Aug. 1	21	F.	Adult	medium
Aug. 1	22	F.	Adult	none
Aug. 1	23	M.	1	medium
Aug. 3	24	?	?	light
Sept. 18	25	F.	Adult	light

parasitized sample examined from the study area represents very light infestation. Heavy lungworm infection is a usual precursor to pneumonia and this may have been the condition on the study area in the early forties.

Only two unthrifty sheep were observed during the study period. Both were thin old ewes, and it was doubtful if either would survive another winter. A total of four diseased sheep were examined. A ewe lamb was collected about the middle of January in 1956 by Mr. Frank Jones, Forest Ranger at Canmore, and sent to the University Zoology Department. The lamb had lesions in the mouth and on the forelimbs below the knee joints. Dr. H. N. Vance, veterinary pathologist, reported that the lesions in this lamb were quite suggestive of a condition which

Fig. 17. Foot rot in bighorn ram (note swollen joint). (Photo by Dr. R. B. Miller).

occurs commonly in domestic sheep, that is, contagious ecthyma or 'sore mouth'. On Feb. 27, 1957, Jones sent in the head and a swollen right forelimb of a four-year ram that had been collected near the Kananaskis Ranger Station (Fig. 17). The ram was in an emaciated condition. Dr. G. S. Wilton, veterinary pathologist, found that, "direct smears from the foot lesion revealed the presence of a necrophorous bacillus indicating foot rot. Absesses were noted adjacent to the joints and Corynebacterium pyogenes was recovered on culture". Jones wrote that this was the first time that foot infection had been observed in the wild sheep of the Kananaskis area. On Sept. 9, 1956, Wm. T. Balmer, forestry officer on the Sheep River, shot a six-year ram with a deformed front hoof. One phalanx had an overgrown unguis that was hollow underneath and the other phalanx was twisted and twice normal size. The foot had apparently suffered from some injury or disease, healed and was of little use. The ram was taken between the study area and the former Kananaskis Game Preserve. On May 26, 1956, a yearling ram was collected that had absesses on both lungs. Dr. Vance examined the preserved infected tissue and suggested the lesions were probably due to a suppurating infection commonly seen in domestic animals and generally caused by species of the bacteria Spheropherus or Corynebacterium.

Fig. 18. Bighorn winter range that has been heavily grazed by cattle.

Fig. 19. Bighorn and horses grazing on hayfield.

There appears to be a low incidence of mouth disease in bighorn. During the study period only two ewes were observed with lumps on their jaws. Out of 21 skulls examined that still retained lower jaws, three showed evidence of some necrosis. Only four upper jaws of 92 ram skulls appeared to show evidence of malocclusion.

Competition. From June until October domestic cattle have access to approximately 100 acres of bighorn winter range, i.e., Windy Point Mountain and a two mile strip along the Sheep River. The slopes of Windy Point Mountain show little sign of range depletion, i.e., the dominant plants of the Festuca scabrella association are still well represented. However, the flat area above the river has been grazed to the point where several undesirable plant species have taken hold (Fig. 18). The balance of the bighorn winter range described earlier is accessible to six to ten horses during the winter and summer. From the middle of April until the cattle arrive in June, large numbers of deer feed on the green shoots of grasses and sedges that grow on the winter range of the bighorn. In recent years small numbers of elk have been observed infringing on the northwestern and eastern limits of the bighorn winter range. In every case mentioned the competition with the bighorn for winter forage was direct

and varied from partial to considerable. Sheep were observed grazing in close association with deer and horses on several occasions and with elk on one occasion. In spite of an overlap of feeding habits, the importance of forage competition between bighorn and other animals on the study area is questionable. Consider the changes that took place on the hay meadow which forms approximately 10 percent of the winter range. In 1954 the hayfield was composed of 24 acres of brome and timothy. The hay was cut and stacked and a corral was built around it. Only the stubble was available to the sheep. In 1955 the 24 acres of hay was baled and picked up and the stubble was utilized by the sheep (Fig. 19). In 1956, nine acres at the west end of the hayfield and a new addition of 11 acres of former natural winter range were broken and left over winter, i.e., the winter range was reduced by 20 acres. In 1957 the 20 acres were seeded to timothy and a cover crop of oats. The oats were cut with a binder and stooked and the hay in the centre area was mowed and stacked. About 30 oat stooks were left in the field and these were cleaned up by the sheep early last winter. The hay stack was accessible to the sheep, but was not utilized by them . In spite of rather violent fluctuations in a portion of their winter range sheep returned in relatively constant numbers every year. It would appear that during the past four winters the carrying capacity for bighorns has not been limited by the amount of available forage. In other words,

from the standpoint of forage capacity the bighorn range has not reached saturation, but from the standpoint of intraspecific tolerances and the present amount of open range it appears as though saturation has been reached. The constant degree of gregariousness has already been emphasized. The encroachment of poplar trees on former open range has been mentioned. The further a sheep wanders from escape terrain the greater is the requirement for an open view in all directions, i.e., a sheep must be able to see approaching danger and have adequate time to take cover. The less open space there is, the less distance a sheep will wander from its escape terrain. When this phenomenon is combined with an apparent level of intraspecific tolerance it serves as a natural control against over-population, provided there is a reasonable balance between escape terrain and open range that has not been overgrazed by other species. Some sheep on the East Slopes of the Rocky Mountains are associated with escape terrain and large open stands of timber during the winter. It is believed that these are marginal areas, since the bighorn's fear of closed timber stands has been observed many times. Other areas that are considered as marginal wintering grounds are some of the high wind swept slopes of normal summer range and the deciduous forest areas of river valleys. The sheep losses in these areas would fluctuate considerably depending on snow conditions and predation.

Fig. 20. Variation in horn development of three 3+ rams (note difference in curl).

Fig. 21. Variation in horn development of three 3+ rams (note difference in spread).

MANAGEMENT PROBLEMS

Hunting. Under the present hunting regulations in Alberta it is illegal to kill a bighorn ram with less than a 3/4 curl. In order to determine what age classes would be harvested and what exceptions might occur under the present system, a series of 104 ram heads, largely from the Luxton collection, were aged and the horns measured (Table XX). From a given set of horn measurements it is possible to determine the approximate fraction of a full curl from the relation * $\frac{L^2 - S^2}{C}$, where L is the horn length, S is the spiral distance or $\frac{\text{spread}}{2}$ - 1/2 inch and C equals the circumference of a circle with horn diameter D (see definition of horn measurements, Table XX). Considerable variation occurs in all three measurements in animals of the same age (Figs. 20 and 21); however, the fraction of a full curl is largely dependent on S and C. For example, a 5+ ram with a 24" spread and a right horn 28 3/4" long with a 12 1/2" diameter had 0.67 of a full curl. Another 5+ ram with a 19" spread and a right horn 28 1/2" long and only 10 1/2" in diameter had 0.82 curl. Two of the seventeen 3+ heads examined were legal, i.e., they had a 0.75 curl or better. Both rams had tight curls or horns with narrow spread and small diameters. Eleven of the 21

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* I am indebted to Mr. R. J. Watson, student engineer, for devising this formula.

Table XX. Ram horn measurements in inches.

Age	N	Length Mean	Length Range	Base Mean	Base Range
1	6	7.75	7.25- 8.00	5.75	5.00- 6.50
1 plus	10	11.00	8.50-18.50	7.50	6.25-11.00
2	2	13.50	-	8.50	-
2 plus	22	20.25	15.00-24.00	12.00	10.00-13.75
3	10	22.70	19.00-28.00	13.25	11.75-14.00
3 plus	32	26.00	18.75-30.00	14.25	12.50-16.00
4	7	28.00	25.00-29.75	14.50	14.00-15.50
4 plus	38	29.00	23.25-32.00	14.50	10.50-16.00
5 plus	20	29.75	26.00-33.25	14.50	13.50-15.50
6 plus	21	32.50	27.00-37.00	14.50	13.25-15.25
7 plus	16	32.50	30.00-35.00	14.75	14.00-15.25
8 plus	9	33.25	32.00-36.25	14.50	13.50-15.00
9 plus	7	32.50	30.50-37.00	14.25	14.00-14.75
11 plus	5	32.50	28.75-37.50	15.00	14.50-15.50
12 plus	2	34.00	-	14.75	-
	207		7.75-37.50		5.00-16.00

Age	Spread N	Spread Mean	Spread Range	Diameter N	Diameter Mean	Diameter Range
2 plus	9	20.25	19.00-22.00	11	12.00	11.00-13.00
3	5	19.00	18.00-20.50	5	11.25	10.50-12.25
3 plus	16	18.50	16.00-22.25	17	11.75	10.25-13.25
4	3	18.00	17.00-19.00	3	11.75	11.25-12.50
4 plus	19	19.50	17.25-23.50	23	12.00	11.00-13.25
5 plus	10	19.75	17.00-24.00	10	11.75	10.50-12.50
6 plus	11	19.25	17.50-21.00	12	11.75	10.00-12.50
7 plus	8	20.00	18.25-23.25	8	12.00	10.25-13.25
8 plus	5	20.00	19.00-22.00	5	11.50	10.75-12.00
9 plus	4	19.75	17.50-23.00	4	11.50	10.75-12.00
11 plus	1	19.00	-	2	11.50	-
12 plus	1	19.00	-	1	11.25	-
	92		16.00-24.00	101		10.00-13.25

Definition of Horn Measurements:

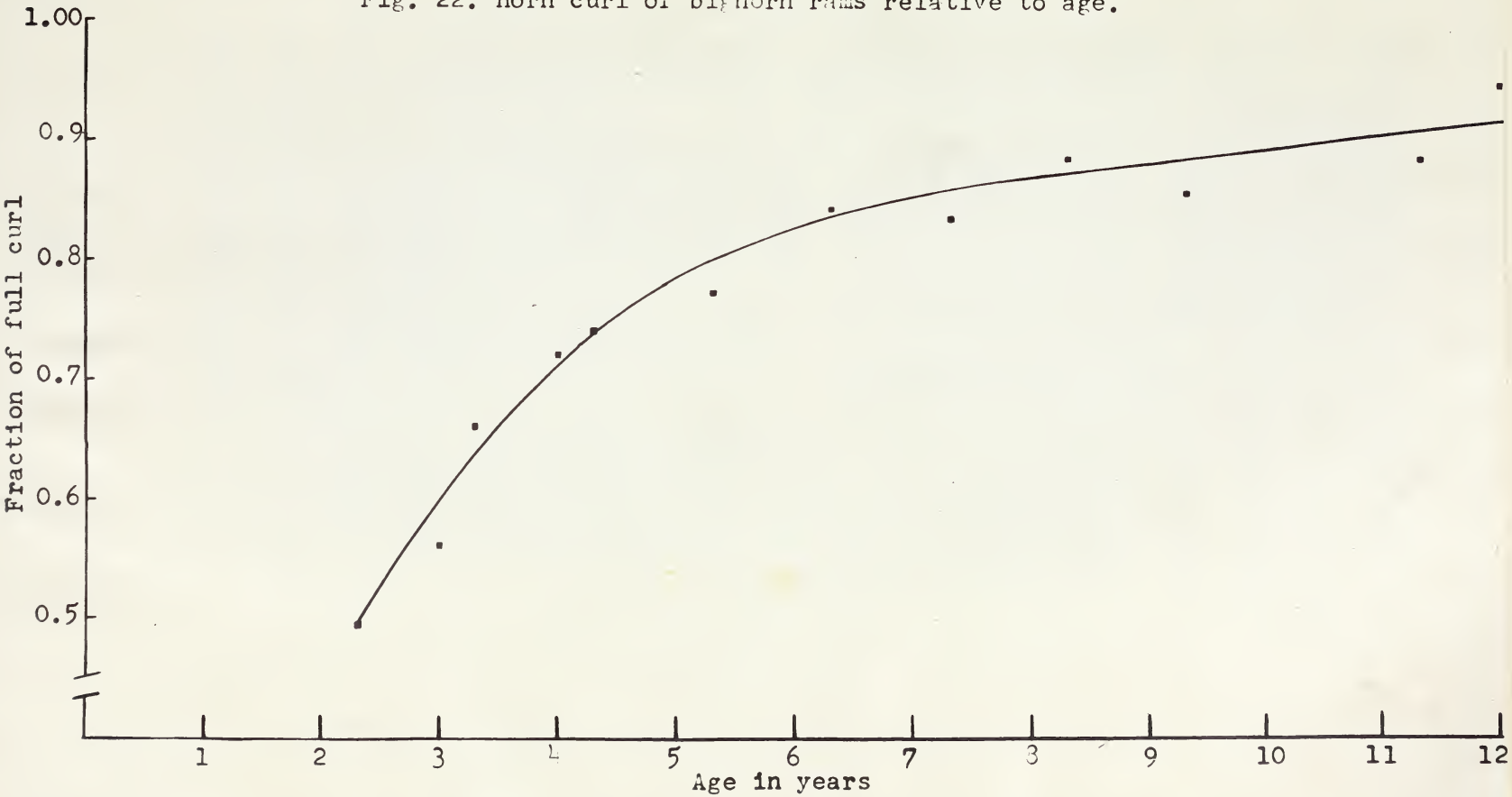
Length: Measured along the middle of the frontal plane from the base to the tip.

Base: Circumference of the base measured at right angles to the plane of the spiral.

Spread: Greatest distance between horn tips.

Diameter: Measured medially from the anterior margin at the base to the posterior margin of the horn.

Fig. 22. Horn curl of bighorn rams relative to age.



4 ram skulls examined had 3/4 curls or longer. Seven out of ten 5+ heads had 3/4 curls. Most six and seven-year-old rams exceeded the 3/4 curl; however, some exceptions occurred due to excessive brooming (note range in Table XXI). Generally speaking rams 5 years or over had a 3/4 curl or longer (Fig. 22).

Table XXI. Fractions of full curls of rams aged 2 to 12 years.

Age	Mean fraction of full curl	Range	Percent having 3/4 curl or longer
2	0.47	0.35 - 0.54	0
3	0.56	0.44 - 0.79	0
3	0.66	0.41 - 0.76	12
4	0.72	0.71 - 0.76	25
4	0.74	0.61 - 0.81	52
5	0.77	0.67 - 0.94	70
6	0.84	0.68 - 1.00	90
7	0.83	0.71 - 1.01	72
8	0.88	0.84 - 0.95	100
9	0.86	0.75 - 0.98	100
11	0.87	0.68 - 1.12	100
12	0.94	-	100

Fig. 23. A minimum sized legal head.

At present both the hunter and the enforcement officer are faced with the problem of recognizing a legal head. A legal head may be described as having one horn that can be intercepted at both the front of the horn base and the horn tip by a straight line through the eye (Fig. 23). This is a rapid method of identifying a legal head in the field. Although it includes heads with slightly less than a 0.75 curl, some of these possess broomed horns and wide spreads and should be harvested.

Table XXII gives the numbers of sheep taken by hunters from the study area for the past five years, i.e., before and after the 3/4 curl legislation of 1956. The harvest is expected to pick up again in the fall of 1959 when a good percentage of rams born in 1955 will have grown legal-sized heads. Some losses of young rams are to be expected. However, quality is rated above quantity in the management of a fine trophy animal such as the bighorn.

Table XXII. Numbers of bighorn sheep harvested from the study area (1953 to 1957).

Year	Rams	Ewes
1953	13	3
1954	12	0
1955	11	1
1956	0	0
1957	1	0

Winter Range Improvements. The winter range of the bighorn on the study area has been subjected to both severe and moderate grazing which varies with availability and competition. No control measures can be taken as far as slope exposure, wind, snow and sun relationships are concerned; however, cattle should be prevented from utilizing a portion of what is definitely sheep winter range. A fence line could be constructed from the north side of the ranger's east pasture to Windy Point Mountain. The fence would serve to prevent cattle from further depleting a two mile strip of bighorn winter range. In the spring of 1956 a few elk were sighted on east Missing Link. In 1957 a noticeable increase of elk appeared on both Missing Link and Windy Point Mountains. It would appear that larger numbers of elk should be harvested from around the study area in order to prevent their contribution to further depletion of bighorn winter range. If the above control measures are taken there is less danger of the winter range becoming depleted to the point where sheep survival is dependent on the forage that is not eaten by other animals.

It was pointed out earlier that at present bighorn sheep numbers on the Sheep River winter range appear to be regulated by intraspecific tolerances and the amount of open range at their disposal. If the statement is true,

sheep numbers could be increased by an expansion of winter range. The expansion could be achieved by controlled burning or cutting of some of the dense poplar stands that have taken over former winter range. Otherwise, if nature is allowed to take its course and an efficient fire prevention system is maintained, forest succession and encroachment will continue.

Transplanting. It is felt that the present sheep population on the east slopes of the Rockies is at an optimum level. Transplanting of bighorns along the slopes seems out of the question. An interesting possibility for a transplant exists in the badlands of the Red Deer River. As stated earlier, historical records mention bighorn as inhabitants of river valleys and the suggestion that they should be restored to some of these areas should not be overlooked. A logical location to attempt to transplant would be in a new Provincial Park at Steveville. If an area in the Park is investigated and found to have suitable winter range for sheep, a large enclosure should be built to contain the animals until they become accustomed to the area and, where, at the same time, their progress can be observed.

SUMMARY

1. A brief history is given of the Rocky Mountain bighorn sheep Ovis canadensis canadensis.

2. The study area is in the vicinity of the Alberta Biological Station which lies in the foothill and mountainous terrain twenty miles west of Turner Valley, Alberta, on the Sheep River drainage. The area includes both the lower, more eastern, winter range, and the higher, more western, summer range of the bighorn sheep.

3. The appearance of the bighorn is described; coloration and horn growth are the most distinguishing features.

4. The numbers of rams appearing on the winter range vary from year to year. However, the numbers of ewes and yearlings appearing each year are relatively constant. Different ram-ewe ratios show no apparent effect on lamb production.

5. A general movement to high summer range occurs in May and June and a return to the winter range of the foothills occurs during the late fall.

6. The spring diet of the bighorn is mainly grasses and sedges. Forbs, mostly legumes, constitute a large portion of the summer diet. Poplar, willow and gooseberry are important browse species in the late summer.

7. Sodium appears to be the most important element that attracts sheep to natural mineral licks along the Sheep River canyon.

8. The breeding season extends from the last week in November until the middle of January. The gestation period is 180 days. Both ewes and rams appear to reach sexual maturity at two and a half years of age.

9. Ewes on the study area have a shorter life span than rams. Incisor damage in ewes might be a cause of the differential mortality.

10. Predation, accidents, parasites and disease appear to be limiting factors that vary from range to range.

11. Evidence of competition for forage with other species was found. However, competition does not appear to be a critical factor in holding the sheep population at its present level. Sheep numbers are limited on their wintering areas by intraspecific tolerances and a requirement for a certain amount of open range near escape terrain.

12. Horn growth varies considerably in rams of the same age. In order that trophy rams be properly harvested, heads with horns slightly less than a 3/4 curl should be taken.

13. The sheep population along the East Slopes appears to have reached saturation. The numbers are not great, therefore it is suggested that management practices should be designed which will at least maintain those areas that are established as sheep winter range.

ACKNOWLEDGEMENTS

Assistance received from Canadian Industries Limited, the University of Alberta and the Department of Lands and Forests was acknowledged in the introduction. In addition, co-operation was received from many individuals. Special thanks are due to Mr. D. A. Boag for a large contribution of his enthusiasm, time and energy. Thanks go to other students at the Biological Station, especially R. G. Miller and D. H. Sheppard for their assistance in various phases of the investigation. Acknowledgements are due to both the Alberta and Eastern Rockies forestry personnel for their assistance in many phases of the work. Other contributions were made by the Botany Department, University of Alberta; Provincial Veterinary Laboratory and the Wyoming Game and Fish Laboratory. I am grateful to Mr. N. K. Luxton of Banff for the use of his collection of ram skulls. It was only through the co-operation of the many outside agencies and individuals that the collection and evaluation of a large part of the information was possible.

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